BTC++

Learn how Bitcoin Multi-Sig works

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3-OF-5 QUORUM

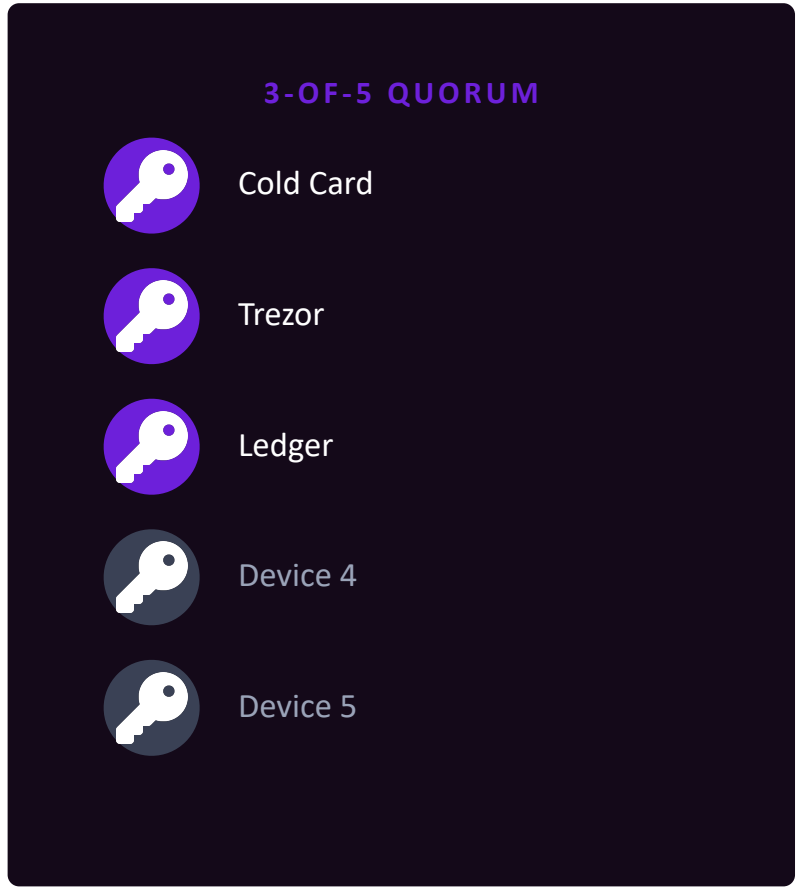
Desired Learning Objectives

- What is multi-sig and why use it?
- How does it work under the hood?
- Hands on experience!

What Is a Multi-Sig Wallet?

- A wallet that requires **multi**ple **sig**natures to spend from.
- Spending requires M of N signatures: ex. (“3 of 5”) (“2 of 3”).
- You can lose some keys without losing funds.
- The keys can live in different places, with different people, and be on different device brands.

A normal single-key wallet with your life savings is risky, loss or theft means you lose it all.



Use Multi-Sig to safeguard extreme value:
Enterprise Treasuries, Small Business, Life Savings

Know Your Threat Model

What are we actually defending against?

Remote Attackers

Exchange hacks, Malware

Physical Attackers

“Wrench attacks”: coercion, robbery

Ourselves

Lost seeds, broken devices. Pass on your bitcoin with a multi-sig Inheritance scheme.

Insiders

A rogue employee. Protect your company with an auditable policy-driven treasury: who can spend and how many approvals does it take?

Natural Disasters

Fire, flooding, hurricanes

Multi-Sig best practices

01

Never store a quorum of keys in one place

A thief shouldn't be able to break in and find a quorum of keys to steal funds.

02

Make yourself travel

Obtaining a spending quorum should take time.

03

Use access-controlled locations

Don't let someone stumble upon your devices/seed phrases.

04

Diversify hardware

Mix device manufacturers to avoid single-vendor exploits.

05

Health-check every 6 months

Confirm each device still works, update firmware. Make sure you haven't already lost a key.

06

Never put private keys online

Not in email, not in password managers, not in cloud photos, not in notes app.

blog.casa.io/vault-key-distribution

Under the Hood:

We'll use Bitcoin RPC (Remote Procedure Commands) to walk through the concepts.

Primer on Digital Signatures

Private keys and public keys exist in pairs. A private key creates a signature and its matching public key verifies that the signature was created by its corresponding private key.

So to sign something:

signature = signature_algorithm(private_key, hash(data))
is_valid = verify_signature(public_key, hash(data), signature)

In Bitcoin,
The **seed phrase** is a master backup of all your private keys in your wallet.

Whoever has a **private key** can create a valid signature to spend the coins controlled by that key.

The **public key** lets the network verify a signature was created by someone with access to the private key.

The bitcoin **address** is a user-friendly string for receiving bitcoin (bc1q57jkgfznapz76kycdkvu7jpynpdqnfq3rtvyv4). It is derived from a single public key, or from a script containing multiple public keys.

signature = sign(private_key, hash(transaction_details))

First, we need our 5 XPUBs

Your seed phrase is used to derive a master **extended private key** or **XPRV**. The master XPRV is the root of your public+private key-pair tree. An **XPUB** or **Extended Public Key** gives you the public side of a branch in the key tree. It can generate receive addresses for that branch but not spend funds or reveal private keys. **Derivation Paths** tell us where we are in the key tree.

```
Seed phrase
  |
  v
Master XPRV (m)
  |
  +-- m/48h/...
  |     BIP48 multi-sig branch
  |     |
  |     +-- XPUB -> multisig receive addresses
  |     +-- XPRV -> multisig signing keys
  |
  +-- m/84h/...
        BIP84 single-sig branch
        |
        +-- XPUB -> singlesig receive addresses
        +-- XPRV -> singlesig signing keys
```

History: *introduced by BIP 32 "Hierarchical Deterministic Wallets" (Pieter Wuille, 2012). Before BIP 32, one seed produced one address; now one xpub derives an endless tree of watch-only addresses.*

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```
# These are our 5 wallets
bitcoin-cli createwallet "signer1"   # My Cold Card (fingerprint: f242c5cc)
bitcoin-cli createwallet "signer2"   # My Trezor    (fingerprint: 8a2f52d6)
bitcoin-cli createwallet "signer3"   # My Ledger
bitcoin-cli createwallet "signer4"   # My other device
bitcoin-cli createwallet "signer5"   # My other device

# Each hardware signer exports a BIP48 multisig account xpub. Fingerprints are short device identifiers.
hwi --fingerprint f242c5cc getxpub "m/48h/1h/0h/2h"
# master key / purpose' / coin type' / account' / script type'
# master XPRV / BIP48 multisig / testnet / account index 0 / native SegWit P2WSH

# Here are the resulting XPUBS (tpub in regtest. can be ypub, zpub)
signer1  [f242c5cc/48h/1h/0h/2h]tpubDFYoCXRHHTquZjL8oEs4...vyLK5xmr
signer2  [8a2f52d6/48h/1h/0h/2h]tpubDEjWCPLR6JzWeav6a6g...UTbTp1V9
(+ signer3, signer4, signer5)
```

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The Wallet Descriptor

A **wallet descriptor** is a recipe for generating addresses and defining how coins sent to those addresses can be spent. It states the script type, keys, derivation paths, plus (for multisig) the spending threshold.

```
wsh(sortedmulti(3ofTotal, key1, key2, key3, key4, key5))
```

This is a native-segwit multi-sig script requiring 3 signatures from these 5 key expressions. We'll use XPUBs in here (instead of single public keys) so our wallet can automatically derive new addresses and avoid address reuse, which is a best practice for privacy.

sortedmulti() lets participants list the same cosigner xpubs in any order. It sorts derived public keys lexicographically. This makes coordination easier than using multi() where different orderings derive different addresses.

```
# This is a multipath descriptor.  It combines receive and change paths together using <0;1>.
# Branch 0 is used for receive addresses and branch 1 is used for change addresses.
# Before we had to import receive and change wallet descriptors separately.
wsh(sortedmulti(3,
    [f242c5cc/48'/1'/0'/2']tpub.../<0;1>/*,
    [8a2f52d6/48'/1'/0'/2']tpub.../<0;1>/*,
    ...))
```

https://github.com/bitcoin/bitcoin/pull/22838 *"Be able to specify change and receiving in a single descriptor string"*

How to create a Watch-Only wallet for our Treasury:

```
# Create a blank watch-only wallet
bitcoin-cli -named createwallet \
    wallet_name=treasury \
    disable_private_keys=true \ # This wallet will never store private keys
    blank=true # create with no keys or default descriptors, we will import ours

# Import the descriptor
bitcoin-cli -rpcwallet=treasury importdescriptors '[
  { "desc": "wsh(sortedmulti(3,
                [f242c5cc/48h/1h/0h/2h]tpub.../<0;1>/*,
                [8a2f52d6/48h/1h/0h/2h]tpub.../<0;1>/*,
                ...,
                ...,
                ...))#ujyqzadm",
    "active": true,
    "timestamp": "now" }
]'
```

Receiving Payments

Our new watch-only wallet has everything needed to derive receive+change addresses and spot incoming balances. Every **getnewaddress** rpc call derives the next public key from each signer's xpub and generates a multisig receive address. No signing devices or private keys need to be involved to generate a new receive address.

```
# Generate a fresh address
bitcoin-cli -rpcwallet=treasury getnewaddress

bcrt1qtlg3fhlqm42fwvty4qpfeplepft94qqjsnjf287wj0lyn5y7qu8qyzcdss
```

Spending: The PSBT

Partially Signed Bitcoin Transactions are a standard file format for transactions that aren't fully signed.
There are two approaches for multi-sig:

Round-Robin

walletprocesspsbt
One signer appends a signature and passes the PSBT along to the next signer.

Fan-Out & Combine

combinepsbt
The coordinator fans a PSBT out to everyone, each signer adds a signature, then the coordinator merges them with this rpc.

History: *BIP 174, by achow (2017), shipped in Bitcoin Core 0.17 (2018). Before it, co-signing meant shuttling raw hex and redeem scripts between incompatible wallets.*

Spending: Create the PSBT (a 'draft' transaction)

Use the watch-only wallet to create the transaction (PSBT). You don't need the signing keys to propose a transaction.

```
# Create a PSBT
bitcoin-cli -rpcwallet=treasury walletcreatefundedpsbt "[]" \ # [] so it auto-selects UTXOs to send
  '[{"bcrt1q6ezg3a5...kuu8l": 0.2}]' 0 \ # Send 0.2 BTC to this address, 0 for no locktime restriction
  '{"includeWatching": true}' # Include watch-only coins

# This is the resulting unsigned PSBT, no signatures added yet
{ "psbt": "cHNiGyRYZ/bNEKcC....AAA==", "fee": 0.0000225 }

# Verify the PSBT is correct before we sign!!!
bitcoin-cli decodepsbt "cHNidP8BAH0CAAAA..."
#   out 0.20000000 BTC -> bcrt1q6ezg3a5...kuu8l  (payee)
#   out 0.79997750 BTC -> bcrt1qv99hu0w...lnks   (change)
#   fee 0.00002250 BTC     <-- check amount + destination!
```

Anatomy of a Partially Signed PSBT

```
# Lets add signer1 using walletprocesspsbt and then have a look inside:
bitcoin-cli -rpcwallet=signer1 walletprocesspsbt "cHNidP8B..."
<psbt_with_1_signature_added> # A new PSBT is returned with signer1's signature added

bitcoin-cli decodepsbt "<psbt_with_1_signature_added>" # Below are some fields of interest to point out
{ "tx": {
    "vout": [
      { "value": 0.20000000, "address": "bcrt1q6ezg3a5...kuu8l" }  # Send 0.2 BTC to this address
      { "value": 0.79997750, "address": "bcrt1qv99hu0w...fsfmq" }, # Change goes back to one of our change addresses
   ] },
  "inputs": [{      # This contains info needed for signers to sign this PSBT.
    "witness_utxo": {      # The amount + locking script of the coin this transaction spends
        "amount": 1.00000000,
        "scriptPubKey": "0020 35a47c75...",
     },
    "partial_signatures": {      # The signatures added so far
      "03d03cc3...b976e42a": "304402200dbce390...0501"  # signer1
    },
    "witness_script": {       # The multisig rule of the bitcoin being spent. Lets signers verify this input belongs to
      "asm": "3 <pk1>..<pk5> 5 OP_CHECKMULTISIG"   # the 3-of-5 multisig wallet.
    },
    "bip32_derivs": [     # Shows which wallet derivation path produced each public key in this UTXOs multisig script:
      { "pubkey":"03d03cc3...", "fingerprint":"f242c5cc", "path":".../0/3" }, # signer1
      { "pubkey":"02643c58...", "fingerprint":"8a2f52d6", "path":".../0/3" }  # signer2
      # ... signer2, signer3, signer4, signer5
    ]
  }],
  "fee": 0.00002250
}
```

Key idea: *Each signature is bound to THIS exact transaction. Change any output and every signature already collected becomes invalid.*

Spending: Collect & Combine the Signatures

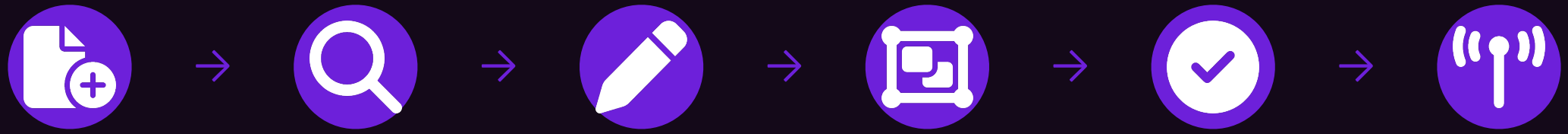
Each signer starts from the same draft, so each returned PSBT carries only its own signature. **combinepsbt** combines the separate copies into one.

```
# Two more signers sign the SAME starting PSBT:
bitcoin-cli -rpcwallet=signer2 walletprocesspsbt "..."
bitcoin-cli -rpcwallet=signer3 walletprocesspsbt "..."

# Merge the three separate PSBT copies into one:
bitcoin-cli combinepsbt '["<psbt_1>","<psbt_2>","<psbt_3>"]'
<psbt_with_a_quorum>

# The partial_signatures field in the resulting PSBT now carries all three signatures:
{ "partial_signatures": {
    "03d03cc3...b976e42a": "304402...01",   # signer1
    "02643c58...cbfbbf83": "304402...01",   # signer2
    "02957c23...b2083952": "304402...01"    # signer3
  }
}
```

Spending: Finalize and Broadcast



Propose	Verify	Sign ×3	Combine	Finalize	Broadcast
walletcreatefundedpsbt	decodepsbt, check amount + destination	walletprocesspsbt, once per signer	combinepsbt merges the signatures	finalizepsbt completes at M sigs	sendrawtransaction

```
# Now that we have a quorum of signatures we need to finalize the PSBT.
# If this transaction is fully signed it will produce a serialized raw transaction hex.
bitcoin-cli finalizepsbt "<psbt_with_a_quorum>"
<raw_transaction>

# Now we can broadcast this transaction to the network:
bitcoin-cli sendrawtransaction "020000000001011b9367cf2d375ed6acdf1a632071db..."
```

Spending: Finalize and Broadcast

```
# Lets inspect some of the fields:
bitcoin-cli decoderawtransaction "020000000001011b9367cf2d375ed6acdf1a632071db..."

{
  "txid": "602b4ce7…b14d15",
  "vin": [
    {
      "txid": "b36463c1…931b:0",
      "txinwitness": [
        "",                          # OP_CHECKMULTISIG dummy
        "3044…44601",                # signer2 sig
        "3044…fec9f01",              # signer1 sig
        "3044…710501",               # signer3 sig
        "5321…55ae"                  # witness script: OP_3 <5 pubkeys> OP_5 OP_CHECKMULTISIG
      ]
    }
  ],
  "vout": [
    { "value": 0.79997750, "address": "bcrt1qv99hu0w…fsfmq" },
    { "value": 0.20000000, "address": "bcrt1q6ezg3a5…kuu8l" }
  ]
}
```

Lost a Key? Rotate!

If you lose one or even two keys in our 3of5 key vault, no problem. All we have to do is send our bitcoin using the 3 surviving keys into a fresh vault.

```
# First get a replacement signer key XPUB:
hwi --fingerprint <new_fingerprint> getxpub "m/48h/1h/0h/2h"

# 2. New 3-of-5 descriptor: 4 surviving xpubs + the new one:
wsh(sortedmulti(3,<xpub1>,<xpub2>,<xpub3>,<xpub4>,<xpub5b>))
bitcoin-cli getdescriptorinfo "$NEWDESC"
bitcoin-cli createwallet "treasury2" true true
bitcoin-cli -rpcwallet=treasury2 importdescriptors '[ ...new desc ]'

# 3. Sweep old vault -> new vault (a normal 3-of-5 spend):
bitcoin-cli walletcreatefundedpsbt # Then add 3 signatures, finalize, then broadcast
```

Casa

Why Casa? Your Personal Swiss Bank

Casa helps the sovereign individual custody their own Bitcoin. **Casa never holds a quorum of your multi-sig private keys** and can **never** spend your funds.

- No KYC required for vaults or inheritance.
- Casa holds 1 of your keys, will only sign after verification. Duress support.
- OTC trades, buy/sell within app, team signing, custom solutions.
- 24/7 white-glove customer service.
- Business and Enterprise solutions, address whitelisting.
- Anti-Phishing support: call detection, optional travel rules, customer support verification codes.
- Sovereign recovery instructions. Import to Sparrow.
- Free Trial

Promo code - 3 months free:
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https://casa.io/pricing?ref=29a0116e